Results of underground mine studies to assess diesel particulate exposures and control technologies

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Abstract — *During the past several years, the Mine Safety and Health Administration (MSHA) has conducted studies in underground mining operations to obtain information on occupational exposures to diesel particulate (DP), mine environmental DP levels and on the effectiveness of methodologies used to control DP. The studies conducted were representative of four coal mines and 10 metal mines. The metal mines included two lead-zinc mines, one limestone mine, two potash mines, one zinc mine and four salt mines. Three of the four coal mines were using disposable diesel exhaust filters to remove particulate from the exhaust and one was using a reusable wire mesh filter.*

Results of these studies indicate that average DP levels in coal mines not using exhaust filters range from 0.9 to 2.1 mg/m³. The use of exhaust filtration devices reduced these levels by about 50% to 90%. Studies conducted in metal and nonmetal mines showed average DP levels ranging from 0.3 to 1.6 mg/m³.

Introduction

In 1988, an advisory committee, appointed by the Assistant Secretary of Labor, released a report (US Dept. of Labor, 1988) on "Standards and Regulations for Diesel-Powered Equipment in Underground Coal Mines." One of the recommendations was for the Secretary of Labor to set in motion a mechanism whereby a diesel particulate standard could be set. Subsequent to that report, MSHA established a committee whose objective was to review all available literature and "state of the art" technology to establish such a standard.

To ensure that all relevant material was considered, the Agency, on Jan. 6, 1992, issued an Advanced Notice of Proposed Rule Making (ANPRM) for diesel particulate (DP). The ANPRM sought additional information that would assist MSHA in establishing a rule for occupational exposure to DP in the mining and mineral processing industries. The ANPRM sought information relative to the specific areas of exposure limits, risk assessment, consideration of other information, sampling and monitoring methods and feasibility.

Following the release of the advisory committee report in 1988, MSHA, the US Bureau of Mines (USBM) and the National Institute of Occupational Safety and Health (NIOSH) expanded their programs to:

- Develop and evaluate methods applicable to the measurement of DP levels in underground coal mine environments and
- Quantitate occupational DP exposures in underground coal mine environments.

These programs were later expanded to include the assessment of occupational exposures at underground metal and nonmetal mining operations.

In addition to the above programs, the USBM expanded its programs for the development and evaluation of technology to reduce or control particulate emissions from diesel-powered equipment. And NIOSH initiated an epidemiological study of miners in the metal and nonmetal mining industry. In the USBM effort, particular emphasis was placed on developing and evaluating exhaust aftertreatment devices for reducing particulate emissions from diesel equipment.

This paper discusses the results of additional studies conducted by MSHA shortly before and after the ANPRM. These studies focused on obtaining additional information on DP occupational exposures and mine environmental levels, as well as on the evaluation of methodologies presently under consideration for controlling DP in underground mining operations.

Measurement of DP. To date, the primary methods investigated to assess DP concentrations in underground mines include:

- Collecting a sample using a three-stage inertial sampler that separates the sampled aerosol into a supermicrometer respirable fraction and a submicrometer fraction; and, analyzing the submicrometer fraction using either a gravimetric or thermal desorption/combustion analytical technique (thermaloptical method);
- Collecting a sample using a respirable dust sampler and analyzing the noncombustible part of the collected sample using a gravimetric analysis (referred to as the Respirable Combustible Dust [RCD] method).

The thermaloptical method measures the elemental carbon collected in the submicrometer fraction. The elemental carbon is then used as a surrogate to estimate the DP content of the sample.

These methods have been reported on by three different groups of researchers. The inertial sample-gravimetric analysis method has been evaluated by Tomb et al. (1990), Haney et al. (1989), Cantrell et al. (1990) and Rubow et al. (1990). The inertial sampler method used in conjunction with the thermal desorption-combustion analytical technique is being evaluated by NIOSH (1993), (Birch, 1991). Gangal et al. (1990) has reported on a study that evaluated the RCD analytical technique. Evaluations of these sampling methodologies have shown that:

- DP concentrations in underground coal mines can be

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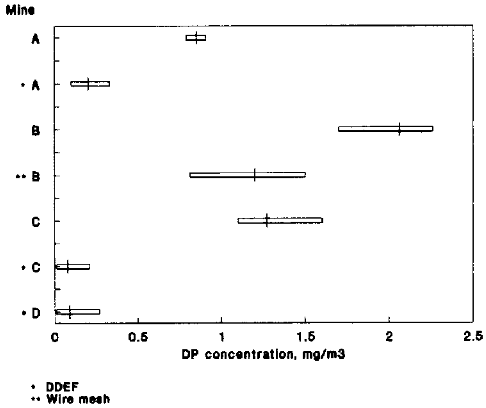

Fig. 1 — Occupational exposures (coal mines).

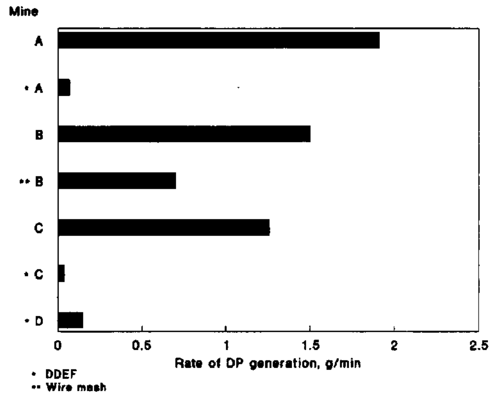

Fig. 2 — Rate of DP generation (coal mines).

determined to within 15% (for submicrometer concentrations greater than 0.3 mg/m^3) using an impactor sampler and gravimetric analytical technique (Cantrell, 1992b). Below 0.3 mg/m^3, mineral dust contamination can affect the accuracy of the determination.

- Based on preliminary laboratory test data, DP concentrations between about 0.005 and 0.6 mg/m^3 can be determined using an impactor sampler and thermaloptical analytical method. Using this sampling and analytical method, it is estimated that DP concentrations down to about 0.1 mg/m^3 can be determined to within 15% (NIOSH, 1993).
- The three-stage inertial sampler may not be applicable to DP determinations in underground metal and nonmetal mines because of the substantial amount of supermicrometer DP that is emitted from diesel equipment not equipped with exhaust aftertreatment devices (Cantrell et al. 1992a). Further investigative work needs to be done to determine under what circumstances the three-stage inertial sampler is applicable to sampling in metal and nonmetal mines.
- DP concentrations in underground metal and nonmetal mines can be determined to within 5% using the respirable dust sampler and gravimetric determination of the noncombustible content of the sample (Gangal et al. 1993). However, this method is not applicable to determinations in coal mines. This is because coal dust, the principal mineral in the aerosol, is also primarily carbon.

Underground studies to assess DP levels. MSHA and the USBM have maintained programs that have resulted in the characterization of DP exposure levels in coal and metal and nonmetal mining operations that use diesel-powered equipment.

Before the ANPRM, MSHA had reported on five studies conducted in coal mines and four studies conducted in metal and nonmetal mines (Haney, 1992). The metal and nonmetal mines included two limestone mines, one salt mine and one copper mine. The USBM had reported on five studies conducted in coal mines (Cantrell et al. 1991) and three studies conducted in metal and nonmetal mines (Cantrell et al. 1992). The USBM metal and nonmetal mines included a shale, limestone and quartzite mine. These studies showed that mean DP levels in the haulage areas of coal mines ranged from 0.5 to 1.4 mg/m^3 and in metal and nonmetal mines from 0.2 to 1.4 mg/m^3. Measurements in the return airways of coal mines showed that DP concentrations ranged from about 0.7 to 2.7 mg/m^3.

Subsequent to the ANPRM, MSHA has conducted additional studies (Haney et al. 1992) in four coal mines and 10 metal mines. In addition to gathering information on DP levels associated with different types of mining operations, these studies also evaluated the effectiveness of ventilation practices and exhaust aftertreatment devices to reduce DP levels. The exhaust aftertreatment devices evaluated were only used in coal mines. They consisted of two different types: a disposable type, referred to as a disposable diesel exhaust filter (DDEF) (Ambs et al. 1992), and a reusable type, referred to as a wire mesh filter (WMF). The 10 metal and nonmetal mines included two lead-zinc mines, one limestone mine, two potash mines, one zinc mine and four salt mines. The procedures employed during these additional studies were similar to those used in previous MSHA studies (Haney, 1992).

Results of additional coal mine studies

Figure 1 shows a summary of the occupational exposure measurements obtained by MSHA from studies conducted in coal mines since January 1991. The data represent the average and range of all occupational exposure measurements obtained during a study. A study normally consisted of collecting samples on the continuous miner operator and ramcars for two to three shifts. For all but one of the mines, measurements were obtained with and without the use of a diesel exhaust aftertreatment device.

As shown in Fig. 1, the average DP concentration for occupational exposures, when exhaust aftertreatment devices were not used, ranged from 0.9 to 2.1 mg/m^3. When aftertreatment devices were used, average occupational exposures ranged from 0.1 to 0.2 mg/m^3 when using the DDEF and 1.2 mg/m^3 when using the WMF.

For operations using the DDEF, occupational exposures were found to be reduced by about 90%. For the operation (B) using the WMF, occupational exposures were reduced by about 50%. The higher concentrations at the mine using the WMF was partly attributed to the lower section airflow. The section airflow at the mine using the WMF was 7.5 m^3/s (15,890 cfm). The section airflow at the mines using DDEF ranged from 15 to 30 m^3/s (31,780 to 63,560 cfm).

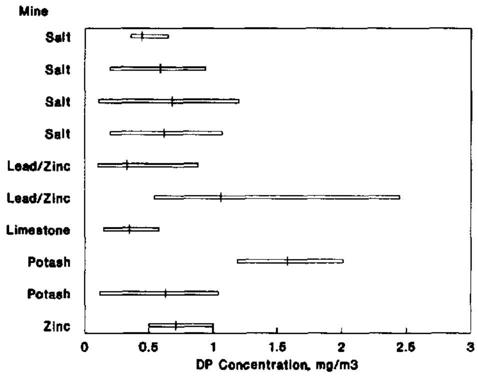

Fig. 3 — Occupational exposures (metal and nonmetal mines).

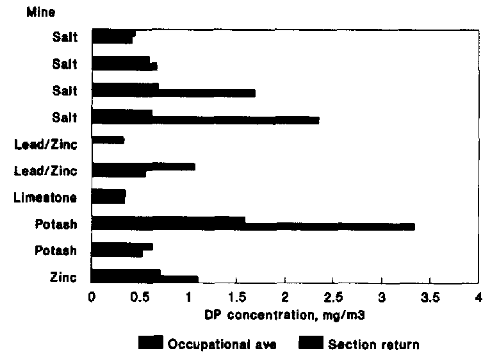

Fig. 4 — DP concentrations (metal and nonmetal mines).

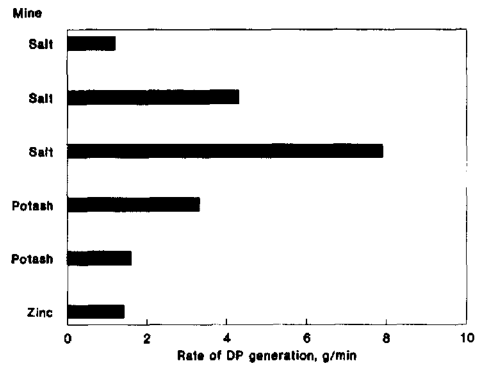

Fig. 5 — Rate of DP generation (metal and nonmetal mines).

Figure 2 shows the rate that DP was generated in the respective mines studied. The generation rate represents emissions from the equipment used in the face area where the personal measurements were obtained. The particulate generation rates were calculated using the concentration of DP in the return airway (corrected for the presence of DP in the intake air) and the return air ventilation quantities. As shown, for operations not using exhaust aftertreatment devices, the generation rates varied from 0.8 to 1.9 g/min. However, the generation rates shown have not been normalized for the number or horsepower of vehicles operating. For most of these operations, the primary sources of DP emissions were from two to three ramcars. The generation rates measured, when no exhaust aftertreatment was used, were in the range expected (about 1.5 g/min) since the typical particulate generation rate for a ramcar used in coal mines is about 0.5 g/min. The data in Figure 2 similarly shows that the DP generation rate was reduced by about 90% when vehicles were equipped with the disposable filters.

Results of additional metal and nonmetal studies

The occupational exposure measurements obtained in metal and nonmetal mining operations are summarized in Fig. 3. The data is presented in the same format as the data shown in Fig. 2, the average and range of occupational exposures. The metal and nonmetal studies typically consisted of measuring the exposure of diesel production equipment operators (truck drivers, roof bolters, haulage vehicles) for two to three shifts. None of the metal and nonmetal mines studied were using DDEFs or WMFs.

As Fig. 3 shows, average occupational exposures ranged from about 0.3 to 1.6 mg/m^3. Overall, occupational exposures averaged about 0.7 mg/m^3. Figure 4 shows a comparison of the average occupational DP exposure and the DP concentration measured in the section return. The data shows that, except for three of the mines studied, the DP concentration measured in the return airway closely approximated the average occupational exposure of the work place. For those mines where this was not the case, it was observed that much of the equipment sampled remained upwind of the discharge of other diesel equipment (miners and bolters upwind of trucks while loading).

Figure 5 shows the DP generation rates for the metal and nonmetal mines studied. The generation rates were calculated in the same manner as those calculated for the coal mines studied. As shown in Fig. 5, the generation rates ranged from 1.2 to 7.9 g/min. The generation rates determined for the metal and nonmetal mine operations were typically two to four times those found in coal-mining operations. However, due to the large quantities of air (18 to 117 m^3/s or 38,140 to 247,900 cfm) used to ventilate the working place, occupational exposures were one-half of those found in coal mines. Metal and nonmetal mine particulate generation rates were also not normalized for number and horsepower of equipment in operation.

MSHA's future efforts

MSHA's diesel program objectives will continue to focus on the development and evaluation of technology used to measure DP exposures, the evaluation of technologies available to reduce environmental DP levels, the application of these technologies to a diverse mineral-processing industry and the gathering of information that will enable MSHA to better assess the need for a DP standard for underground and surface mineral-processing operations. In line with these objectives, in the immediate future, MSHA will evaluate the inertial sampling/thermal-optical analytical method developed by NIOSH for measuring DP concentrations.

MSHA will also be involved in a NIOSH study on "Feasibility assessment of the proposed case-control study of lung cancer and diesel exhaust exposure." The purpose of this feasibility study is to provide information on whether historical exposures can be successfully modeled. If it is established that they can, the proposed case control study will be conducted in about eight nonmetal mines. As part of the cooperative effort, MSHA will assist in conducting industrial hygiene surveys that will be used to characterize past and present exposures to DP. MSHA will also continue to monitor the progress and, when possible, participate in research conducted by the USBM.♦

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